Derivation of exp(3) correction factor for universe observed density in quantum gravity calculations

Nige Cook

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1 Density Correction from Emission and Vacuum-Polarization Redshift

In the Final Theory, cosmological evolution is not described by a curved spacetime metric. Instead, the universe is a Euclidean vacuum-polarization engine driven by a repulsive spin-1 $U(1)_G$ field. Matter sources emit gravitons (and other gauge bosons) into this medium; the bosons propagate, lose momentum by vacuum drag, and their number density dilutes as the mean separation between sources increases.

The goal of this section is to derive, from first principles, the effective density correction factor e^3 that appears in the graviton bath seen today. This factor encodes the fact that most of the gravitons we observe were emitted when the universe was denser, and have been redshifted on their way to us.

1.1 Shell picture and source density

Consider a thin spherical shell of matter sources at physical radius R from a chosen origin, with thickness dR. The number of sources in the shell is

$$dN(R) = n(R)\, 4\pi R^2\, dR, \tag{1}$$

where $n(R)$ is the number density of sources at radius R.

In the mechanistic picture, the repulsive $U(1)_G$ flux drives sources apart with a constant fractional expansion rate

$$\frac{1}{L}\frac{dL}{dt} = H, \tag{2}$$

where $L(t)$ is the mean separation between sources and H is the observed Hubble parameter, now interpreted as a vacuum-field repulsion rate.

Thus

$$L(t) = L_0\, e^{H(t-t_0)}, \tag{3}$$

and the number density scales as

$$n(t) \propto \frac{1}{L(t)^3} \quad \Rightarrow \quad n(t) = n_0\, e^{-3H(t-t_0)}. \tag{4}$$

The matter density is $\rho(t) = m\, n(t)$, so

$$\rho(t) = \rho_0\, e^{-3H(t-t_0)}, \tag{5}$$

where $\rho_0 \equiv \rho(t_0)$ is the present density.

Differentiating Eq. eq:rho-t gives the continuity equation

$$\frac{d\rho}{dt} = -3H\rho, \tag{6}$$

which here arises from three-dimensional number dilution under repulsive boson dynamics, not from a geometric FRW metric.

1.2 Emission power from a shell

Let the graviton emission power per unit volume be proportional to the local matter density,

$$P_{\rm em}(t) \propto \rho(t). \tag{7}$$

For the shell at radius R at emission time t, the proper volume is

$$dV(t) = 4\pi R^2\, dR, \tag{8}$$

so the total emitted power from that shell is

$$dP_{\rm em}(t) \propto \rho(t)\, dV(t) = \rho_0\, e^{-3H(t-t_0)}\, 4\pi R^2\, dR. \tag{9}$$

It is convenient to parameterise the shell by emission time t rather than radius R, because the graviton travel time to the origin is directly related to $t_0 - t$.

1.3 Vacuum-Polarization Redshift: energy and arrival rate

As gravitons propagate through the vacuum-polarization field, they lose momentum by vacuum drag. In the Final Theory, this is the physical origin of redshift. The graviton energy scales as

$$E(t) = E_0\, e^{-H(t-t_0)}, \tag{10}$$

so an emission interval $dt_{\rm em}$ at time t corresponds to an observer interval

$$dt_0 = e^{H(t_0-t)}\, dt_{\rm em}, \tag{11}$$

and the arrival rate is reduced by a factor $e^{-H(t_0-t)}$.

Thus the observed power from the shell at time t is reduced by two factors:

- energy redshift: $e^{-H(t_0-t)}$,
- arrival-rate dilation: $e^{-H(t_0-t)}$.

The observed power is therefore

$$dP_0(t) = dP_{\rm em}(t)\, e^{-2H(t_0-t)}. \tag{12}$$

Substituting Eq. eq:dPem into Eq. eq:dP0 gives

$$dP_0(t) \propto \rho_0\, e^{-3H(t-t_0)}\, e^{-2H(t_0-t)}\, 4\pi R^2\, dR = \rho_0\, e^{H(t_0-t)}\, 4\pi R^2\, dR. \tag{13}$$

1.4 Effective weight of emission times

Equation eq:dP0-simplified shows that the contribution of a shell emitted at time t to the present graviton flux is weighted by

$$w(t) \propto \rho_0\, e^{H(t_0-t)}. \tag{14}$$

The factor $e^{H(t_0-t)}$ is the net result of:

- three powers of $e^{H(t_0-t)}$ from the density at emission,
- two inverse powers from energy and arrival-rate redshift.

Physically, this expresses the fact that shells emitted earlier (larger $t_0 - t$) are denser but more redshifted.

1.5 Horizon-scale emission and the e^3 factor

The graviton bath observed today is dominated by emission from sources near the Hubble horizon scale. The characteristic travel time of such gravitons is of order the Hubble time,

$$\Delta t \equiv t_0 - t_{\rm H} \approx \frac{1}{H}, \tag{15}$$

where $t_{\rm H}$ is the typical emission time of horizon-scale gravitons.

The matter density at that emission epoch is

$$\rho_{\rm past} = \rho(t_{\rm H}) = \rho_0\, e^{-3H(t_{\rm H}-t_0)} = \rho_0\, e^{3H(t_0-t_{\rm H})} \approx \rho_0\, e^3. \tag{16}$$

Thus the effective density seen by the graviton bath is

$$\rho_{\rm eff} \equiv \rho_{\rm past} \approx \rho_0\, e^3. \tag{17}$$

This is the mechanistic origin of the e^3 density correction: three powers arise from three-dimensional number dilution over one Hubble time, and the Hubble time $1/H$ is the characteristic propagation time of horizon-scale gravitons in the spin-1 vacuum-polarization engine.